

Climate change mitigation targets set by global firms: Overview and implications for renewable energy

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ARTICLE INFO

Keywords:

Climate change
Mitigation target
Firm
Developing countries
Sustainable development
Renewable energy

ABSTRACT

Global firms are increasingly adopting greenhouse gas mitigation targets in response to climate change. These targets serve as a spur for carbon mitigation initiatives, provide guidelines to select appropriate mitigation actions, and set the standards to measure the progress of the mitigation efforts. Despite their important functionalities, firm-level mitigation targets have rarely been studied. In this paper we aim to provide a comparative view on mitigation targets set by global firms across different countries and industrial sectors. The analysis focuses on four dimensions, i.e., adoption, metric, scope, and stringency. We find Japan far leads the other major countries in terms of target adoption, but the targets of Japanese firms are generally less stringent. Canadian firms are laggards in both target adoption and target stringency. The mitigation targets are also considerably uncommon among Australian firms. Firms in developing countries fall behind in target stringency and display a significantly greater divergence than developed countries in sectoral adoption rate. The European Union firms are most likely to cover the emissions in their supply chains in targets. Target stringency has substantially tightened from 2005 to 2012. For all the countries in this study, around 95% of the firm-level targets are more stringent than the Intended Nationally Determined Contributions submitted to the Paris Agreement. Setting mitigation target has a significant positive impact on both the likelihood of investing in renewable energy and the amount of investment in renewable energy. However, there is no evidence that more stringent targets lead to higher investment. These findings point to the most pressing issues with regard to corporate mitigation target-setting that policymakers and corporate management should address.

1. Introduction

Due to mounting pressures of climate change, firms around the world have started to set up greenhouse gas (GHG) mitigation targets to control the climate impact of their business activities. For firms, target-setting is a vital step in managing climate change risk and precedes specific mitigation actions [1]. The targets can serve as spur for future carbon mitigation initiatives, provide guidelines to select appropriate mitigation actions, stimulate research and eco-innovations, and set the standards to measure the progress of the mitigation efforts [2]. For policymakers, the way corporates set mitigation targets epitomizes the attitude and response of the private sector toward climate change, and is a crucial factor that policymakers should consider in formulating climate policies [3,4]. Further, how the firms design the mitigation

targets may influence the firms' use of renewable energy. Therefore, investigating the way the firms set mitigation targets is an important research topic with important implications for both the climate policy and the development of renewable energy. However, despite its importance, the subject of firm-level target-setting in coping with climate change has not been well addressed in literature [4].

Existing studies on target-setting have primarily focused on targets at the international, national, regional, and sectoral levels [5,6]. Little attention has been paid to mitigation targets set by firms. But consensus is building among policymakers and business leaders that firm-level targets can play critical roles in coping with climate change [4]. The United States (US) Environment Protection Agency (EPA) stresses that it intends to encourage firm-level target-setting through the Climate Leadership Awards, the most conspicuous awards program in the US for

Abbreviations: BAU, business as usual; CDP, Carbon Disclosure Project; CO₂e, carbon dioxide equivalent; EPA, Environment Protection Agency; ETS, Emissions Trading System; EU, European Union; GHG, greenhouse gas; INDC, Intended Nationally Determined Contribution; MtCO₂e, Million tons of carbon dioxide equivalents; SEC, Securities and Exchange Commission; UK, United Kingdom; US, United States

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<https://doi.org/10.1016/j.rser.2018.06.024>

Received 24 October 2017; Received in revised form 11 June 2018; Accepted 11 June 2018

Available online 18 June 2018

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excellent corporate and organizational leadership against climate change.¹ Science Based Target Initiative (<http://sciencebasedtargets.org>), as a joint program by the Carbon Disclosure Project (CDP), the World Wide Fund for Nature, the World Resources Institute, and the United Nations Global Compact, was set up in 2015 to promote scientific methods for setting firm-level targets. These moves signal a growing awareness of the policymakers and the private sector regarding the importance of firm-level target-setting.

In this study we aim to provide a comprehensive overview on the pattern of mitigation targets set by global firms. Specifically, we aim to answer the following three research questions. Is target-setting a common practice for firms in different countries and industrial sectors? What are the distinctive features of the targets? Are the firms' targets compatible with national mitigation goals? Do mitigation targets lead to more use of renewable energy? Answering these questions can serve three purposes. First, comparative analysis can help policymakers identify the leaders and laggards among the countries and sectors in target-setting, so policies can be tailored to induce desirable target-setting outcomes in specific countries and sectors. Second, the results can help policymakers assess the appropriateness of the national targets. If corporate targets are more stringent than national targets, it may imply that there is a potential to further tighten the national targets. Third, our study also serves as a stepping stone to further analysis of mitigation targets, such as the institutional and economic factors that can shape the mitigation targets.

We examine the mitigation targets set by 1495 prominent firms in the largest emitting countries in this study. We focus on analyzing the following four aspects of targets: adoption, metric, scope, and stringency. As in [7], target adoption corresponds to the status of whether a firm has established any emission targets or not. Target metric represents the way GHG emissions are measured, i.e., absolute measure or intensity measure [5]. Target scope defines the range of emissions covered in the target [8]. Target stringency refers to the quantity of emissions to be mitigated as specified by the target, and hence reflects to a certain degree the effectiveness of the target in mitigating climate change [9]. The data are provided by CDP, which builds one of the largest datasets of firm-level climate strategies by major corporates around the world [10]. The countries under study include major developed countries (the US, the European Union (EU) members, Japan, Canada and Australia), and major developing countries (Brazil, China, India, South Africa, and Turkey). The firms in the sample are typically among the largest and most notable ones in each country. This distinguishes our study from research on small and medium-sized firms, which display significant difference in engagement with the climate change problem compared to the large firms [11].

Our study makes four contributions to literature. First, while there do exist a few studies on firm-level mitigation targets, they all focus on a small number of firms in specific countries or sectors, such as supermarkets in United Kingdom (UK) [2] and firms in Netherlands [6]. Through this study, we greatly expand the research scope to global corporates in major emitting countries across all industrial sectors. Second, prior research lacks in connecting the firm-level targets to national goals. We assess the effectiveness of the firm targets by benchmarking firm targets against the Intended Nationally Determined Contributions (INDCs) submitted to the Paris Agreement. The agreement and the INDCs lay out the foundations and plans for international community to move forward on climate change mitigation and adaptation. Third, we investigate the regulatory and economic reasons behind the distribution of targets, and discuss the most pressing target-setting issues that different countries should address. Finally and most importantly, we analyze the relationship between firms' target-setting and their use of renewable energy, a topic that has never been studied

in literature. While there is recent evidence that a firm's target stringency influences its investment in GHG mitigation projects [9], it is unclear whether and how the mitigation target affects the use of renewable energy. Our study deepens the understanding of the development of renewable energy from a corporate perspective.

The rest of this study proceeds in the following way. In Section 2, we review literature related to corporate target-setting. Section 3 illustrates the institutional and economic context around corporate target-setting. Section 4 describes the data sample and method. Section 5 presents the results. Section 6 discusses implications of the results. Section 7 concludes with limitations of this study and future research directions.

2. Literature review

Setting GHG mitigation targets is a central issue in global efforts against climate change. There is a substantial literature on setting international, national, and subnational GHG mitigation targets [4]. Existing studies have examined the methodology for formulating the targets, feasibility of the established targets, approaches for achieving the targets, and economic and environmental consequences of the targets [12–14]. Some recent studies have also investigated sectoral targets. Hamidi-Cherif et al. [15] examine the economic implications of sectoral targets for developing countries. Kuramochi [16] assesses the mitigation potential of the Japanese iron and steel sector, and finds the sector is likely to overachieve the voluntary target it sets for 2030. However, firm-level target-setting has received little attention so far [4].

Various factors can drive the firms to set climate change mitigation targets. Under the framework of institutional theory, firms obtain legitimacy by conforming to the expectations of social players including institutions and stakeholders [17]. The pressures to meet the social expectations drive the firms to adopt specific managerial practices such as target-setting to achieve alignment of corporate and social values [18]. Beside the legitimization reason, profitability is also a driving factor since target-setting is associated with better performance [19].

This study of corporate mitigation targets is related to the literature on the study of firm-level actions in response to climate change. Since the theoretically “first-best” solution of a global carbon pricing system often fails in practice due to political and economic constraints [20], firm-level actions have emerged as an increasingly critical element of the human society's efforts against climate change [1,21]. Persson and Rockström [22] observe that stakeholder pressures and perceptions of risks/opportunities on climate change have fueled a rising willingness of business managers to take actions to curb GHG emissions. This is evidenced by a wide range of mitigation actions employed by the firms, such as reporting and monitoring the climate change performance, using green product design to reduce carbon footprint, replacing conventional energy with renewable energy, and improving eco-efficiency to save energy input [23–28].

Despite the abundance of research on firms' responses to climate change, corporate target-setting remains a less studied topic in literature. Existing studies are either outdated or limited in the breadth of firms. Using a sample of large multinational companies obtained from CDP, Kolk and Pinkse [21] find that more than half of the companies have set up targets to control direct GHG emissions and the target-setting procedures exhibit a great divergence among firms in different sectors. But the study is dated more than ten years ago. Gouldson and Sullivan [2] study the efficacy of voluntary targets set by 7 major supermarkets in UK and find that those targets are in line with the national goals set by policymakers. A few comparative studies have also been carried out but are restricted to a small number of firms in specific countries and sectors. Sullivan and Gouldson [8] compare the targets set by 11 retailers in the US and 9 retailers in the UK, and find UK retailers set more stringent reduction targets and are more prone to addressing emissions in the supply chains. Focusing on firms in Netherlands, Rietbergen et al. [6] analyzes in detail the target-setting

¹ <https://www.epa.gov/climateleadership/center-corporate-climate-leadership-goal-setting>, accessed on September 1st, 2017.

procedure under certain energy management and carbon accounting schemes. They stress well-defined criteria and conformity checks should be embedded into the target-setting procedure. Wang [29] compares the mitigation targets in the EU and the US in a spectrum of industrial sectors and analyzes the reasons behind the pattern of target-setting in the two regions.

3. Institutional and economic context of corporate targets

Corporate mitigation targets are closely related to the institutional and economic environment in which the firms operate. In this section, we briefly review the most prominent institutional and economic factors that can shape the firms' target-setting behavior.

3.1. European Union (28 members)

As a pioneer and leader in global climate politics, the EU has adopted strong and proactive climate policies. It approved the Kyoto Protocol as early as 2002. To comply with this first binding international agreement on GHG emissions, the EU launched the EU Emissions Trading System (EU ETS) in January 2005. EU ETS has since become the biggest GHG emissions trading market in the world [30]. The EU has overachieved the first Kyoto target and is on track to meet the target of the second commitment period.² Additional measures have been enacted by member states to cover facilities outside EU ETS. For instance, the Climate Action Plan 2050 of Germany sets sectoral emission targets for all economic sectors.³ Other than emissions trading, there are also programs to promote renewable energy and energy efficiency [31]. At the firm-level, in specific sectors (e.g., retailing), there is evidence that the EU firms take more aggressive actions than the firms of other countries (e.g., the US) in responding to climate change [8].

3.2. United States

The US signed the Kyoto Protocol but never approved it. Right now, the country's most prominent federal policy on climate change is EPA's mandatory reporting program for large emitting facilities [32]. Due to political constraints, federal regulations to limit the quantity of GHG emissions never existed and are unlikely to be enacted any time in the coming future. More advanced regulations such as emissions trading can be validated at the state level. Most notably, a cap-and-trade system called Regional Greenhouse Gas Initiative was launched in 2009 to cover the electricity generators in ten northeastern states. A similar emissions trading system was established by California in 2012 [33]. Most recently on June 1st, 2017, the US President Trump announced that US would withdraw from the Paris Agreement, citing economic reasons [34]. Though the formal exit of the US will likely occur three years later in November 2020 by the requirement of the agreement, researchers worldwide have rushed to assess the impact of withdrawal. Preliminary analysis shows that the US is unlikely to achieve its 2025 goal promised under the agreement [35], but at the global level the US exit can do more good than damage to international actions against climate change [36].

3.3. Japan

Japan is less proactive than the EU in climate policy. The country participated in the first commitment period of the Kyoto Protocol in 2008–2012, but withdrew from the second commitment period. The government opposed the framework of Kyoto Protocol on the ground of

fairness and effectiveness [37]. The most notable climate programs in the country are the Voluntary Emissions Trading Scheme and the Keidanren Voluntary Action Plan. As the names suggest, these programs are voluntary. There is evidence that they suffer from lack of stringency, coherence and transparency [38].

3.4. Australia and Canada

Australia and Canada are climate policy laggards. Both countries participated in the first commitment period of Kyoto Protocol. But Australia did not ratify the treaty until 2008. Canada backed down from the national emission reduction obligations signed in the Kyoto Protocol and eventually withdrew from the treaty in 2012. Also, both countries belong to the highest per capita GHG emitters as a result of resource-driven economies, and have “vacillated between support for and obstruction of strong international climate agreements” [39]. There is no national ETS in Canada. Quebec in Canada has implemented a provincial ETS system in 2013 for companies with an annual emission quantity of more than 25,000 metric tons of CO₂e. Australia had a short-lived carbon tax for 2012–2014 and proposals to replace carbon tax with ETS were rejected.

3.5. Developing Countries (Brazil, China, India, South Africa, Turkey)

For developing countries, climate change poses an especially serious challenge. First, GHG emissions from developing countries are predicted to overtake those of the developed countries before 2050 [40]. China surpassed the US in 2007 to become the world's largest emitter. India is now the fourth biggest emitter. Major developing countries are under increasing international pressures to curb their GHG emissions. Second, developing countries are more vulnerable to the adverse effects of climate change than the developed ones, due to their economic and social development limitations [41]. Third, diverting financial and technological resources to climate change may undermine the economic growth. For developing countries, how to balance of environmental concerns and economic growth is a crucial question.

Finally, we would like to remark that the countries under study play a critical role in the worldwide efforts to cope with climate change. Fig. 1 shows the annual GHG emissions by country for 1990–2014. The global emissions have steadily increased, primarily as a result of the rising emissions from China. The emissions from the developed countries have stabilized and started to decrease in recent years. The share of the five developed countries out of global emissions has dropped from more than 60% in 1990 to less than one third in 2013. The emissions of India have been increasing, but not as fast as China. Overall, the graph indicates that the countries covered by this study emit majority of the global GHG emissions. Therefore, how the firms in these countries respond to climate change would largely determine whether the efforts against climate change will succeed or not.

4. Material and method

The main data used in the study are provided by CDP. CDP builds the world's largest and most detailed database on firm-level climate change performance and strategies by annual surveys. Our sample is composed of 1495 firms covered by the CDP 2013 survey. In the sample, there are 598 EU firms, 391 US firms, 151 firms in Japan, 94 firms in Canada, 75 firms in Australia, and 186 firms in developing countries (71 in South Africa, 9 in China, 46 in Brazil, 39 in India, and 21 in Turkey). Here we distinguish developed and developing countries by the standards of International Monetary Fund.⁴ Due to the small sample size for individual developing country, we bundle them to form

² https://ec.europa.eu/clima/news/articles/news_2013100901_en, accessed on September 1st, 2017.

³ https://unfccc.int/files/focus/long-term_strategies/application/pdf/161114_climate_action_plan_2050_en_bf.pdf, accessed on September 1st, 2017.

⁴ <http://www.imf.org/external/pubs/ft/weo/2008/01/weodata/groups.htm>, accessed on September 1st, 2017.

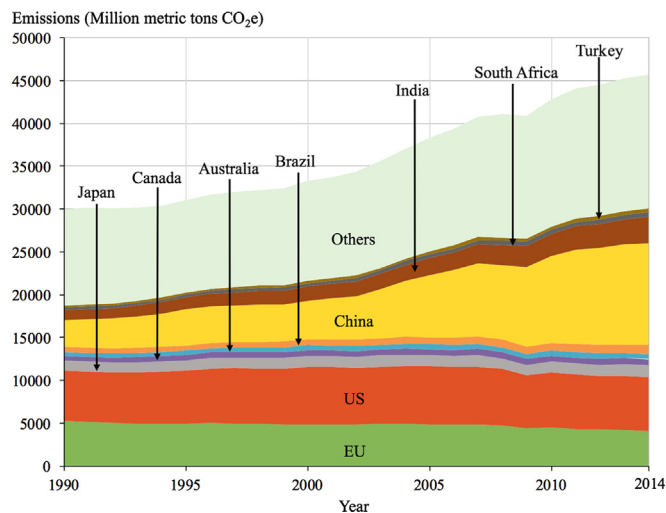


Fig. 1. GHG emissions by countries, 1990–2014. (We obtain the countries' emissions data from CAIT – Country Greenhouse Gas Emissions Dataset maintained by the World Resources Institute [57]. The data exclude emissions from land-use change and forestry).

a single category in our analysis. In fact, major developing countries have adopted similar stance on climate change in prior global summits, thus providing rationale for the bundling. Almost all top emitting countries are included in the sample except Iran, Russia, and Saudi Arabia. These three countries are excluded due to lack of data. Furthermore, the firms are classified into 24 industrial sectors based on the Global Industry Classification Standard.

CDP asks each firm to report if it has any mitigation targets or not. A firm can have multiple targets to cover different business sections or different time horizons. For each target, the respondent should indicate the following characteristics: metric (i.e., whether it is an absolute target or intensity target), reference year (i.e., the year against which emissions are benchmarked), target year (i.e., the year when the intended mitigation should be achieved), percentage of the emissions in scope (i.e., share of emissions covered by the target out of the total emissions in base year), percentage of reduction (i.e., the emission reduction to be achieved in target year as a percentage of the base year emission), completed time (i.e., the percentage of time that has elapsed since the year when the target was set up).

From the above data, we can extract variables on adoption, metric and scope of the targets directly. The stringency of a target depends on several factors, including the reduction quantity from the reference year, the emissions at the time when the target was established, the length of the target horizon, the firm's operational characteristics and technological capability. We represent target stringency as the annual

mitigation rate benchmarked against the reference year of the target. For example, EMC Corporation reports in CDP 2013 survey that the company has a target to reduce 80% of its scope 1 and scope 2 emissions by year 2050, as compared to its emissions in the reference year 2000. We define the target stringency as $80\%/(2050-2000) = 1.6\%$, which means that the target implies an annual mitigation rate of 1.6% from the reference year. We acknowledge that this definition has several limitations. First, the choice of the reference year affects the stringency but we know little about the situation in the reference year. Second, the annual mitigation rate may not exactly capture the level of effort required from the firm to accomplish the target. However, as pointed out by previous literature [42], it is a very hard task to exactly measure the magnitude of efforts needed to accomplish a target. For this reason, we employ the annual mitigation rate benchmarked to the reference year as a proxy for target stringency.

Similar to prior studies on firm-level targets [2,8], we employ a methodology based on content and data analysis to analyze the information from the CDP database. We interpret the results by examining information from other sources such as the countries' climate policies.

5. Results

5.1. Target adoption and target metric

The adoption of the emission targets by firms in different countries are illustrated in Table 1. Table 2 further shows the distribution of targets by industrial sectors. Overall, almost three quarters of the firms in the sample (1099 out of 1495) have set up emission targets. This contrasts with a target adoption rate of 50% in early 2000s [43]. There are 733 firms, almost one half of the sample, adopting intensity targets, while 648 firms have absolute targets. There are 282 firms that use absolute and intensity targets simultaneously.

Among the countries, Japan has the highest adoption rate of targets (97.35%), far ahead of all other countries. Of the 24 sectors under study, Japanese firms have 100% adoption rates in 18 sectors, significantly more than any other countries. The EU and US come at the second and third places with target adoption rates of 76.76% and 73.91%. Australia and Canada have lower adoption rates than other developed countries, with only 56.00% and 47.87% of the firms having emission targets. The developing countries overall all follow have 62.90% of firms setting up emission targets. Among the developing countries, Brazil has the lowest adoption rate of 50% and India has a surprisingly high adoption rate of 79.49%, second only to Japan.

The high adoption rate of the Japanese firms is remarkable, considering that Japanese government opposes the framework of Kyoto Protocol on the ground of fairness and effectiveness [37] and the firms are not subject to national GHG emission regulations such as the EU

Table 1
Distribution of the firms, target adoption and target metrics by countries.

	No. of firms	Target adoption		Absolute target		Intensity target		Absolute and intensity targets	
		No.	Percent	No.	Percent	No.	Percent	No.	Percent
European Union	598	459	76.76%	261	56.86%	328	54.85%	130	21.74%
United States	391	289	73.91%	170	43.48%	171	43.73%	52	13.30%
Japan	151	147	97.35%	114	75.50%	96	63.58%	63	41.72%
Canada	94	45	47.87%	25	26.60%	30	31.91%	10	10.64%
Australia	75	42	56.00%	25	33.33%	29	38.67%	12	16.00%
Brazil	46	23	50.00%	14	30.43%	12	26.09%	3	6.52%
China	9	6	66.67%	2	22.22%	5	55.56%	1	11.11%
India	39	31	79.49%	4	10.26%	28	71.79%	1	2.56%
South Africa	71	46	64.79%	27	38.03%	28	39.44%	9	12.68%
Turkey	21	11	52.38%	6	28.57%	6	28.57%	1	4.76%
Developing Countries	186	117	62.90%	53	28.49%	79	42.47%	15	8.06%
Overall	1495	1099	73.51%	648	43.34%	733	49.03%	282	18.86%

Table 2
Target adoption by country and industrial sector.

	EU			US			Japan			Canada			Australia		
	N	Adoption		N	Adoption		N	Adoption		N	Adoption		N	Adoption	
Energy	22	14	(63.6)	16	10	(62.5)	3	3	(100.0)	21	13	(61.9)	7	5	(71.4)
Materials	58	50	(86.2)	29	21	(72.4)	23	22	(95.7)	23	10	(43.5)	15	4	(26.7)
Capital Goods	91	70	(76.9)	33	25	(75.8)	29	29	(100.0)	4	1	(25.0)	5	3	(60.0)
Commercial & Professional Services	25	18	(72.0)	14	11	(78.6)	3	3	(100.0)	4	2	(50.0)	4	3	(75.0)
Transportation	32	26	(81.3)	14	12	(85.7)	7	6	(85.7)	3	3	(100.0)	4	2	(50.0)
Automobiles & Components	16	12	(75.0)	7	6	(85.7)	9	9	(100.0)	1	0	(0.0)			
Consumer Durables & Apparel	24	13	(54.2)	14	14	(100.0)	9	9	(100.0)	1	1	(100.0)	1	0	(0.0)
Consumer Services	18	14	(77.8)	11	10	(90.9)				2	1	(50.0)	3	2	(66.7)
Media	25	17	(68.0)	8	5	(62.5)	2	2	(100.0)	2	2	(100.0)			
Retailing	14	13	(92.9)	22	15	(68.2)	4	4	(100.0)	6	2	(33.3)	2	1	(50.0)
Food & Staples Retailing	12	12	(100.0)	8	3	(37.5)	2	2	(100.0)	1	0	(0.0)	3	2	(66.7)
Food, Beverage & Tobacco	21	18	(85.7)	24	23	(95.8)	5	5	(100.0)	2	1	(50.0)	2	2	(100.0)
Household & Personal Products	6	6	(100.0)	8	8	(100.0)	4	4	(100.0)						
Health Care Equipment & Services	11	7	(63.6)	15	10	(66.7)									
Pharmaceuticals, Biotechnology & Life Sciences	16	11	(68.8)	15	13	(86.7)	5	5	(100.0)				1	1	(100.0)
Banks	37	30	(81.1)	10	7	(70.0)	2	2	(100.0)	7	3	(42.9)	5	4	(80.0)
Diversified Financials	23	12	(52.2)	18	12	(66.7)	6	5	(83.3)	2	0	(0.0)	5	1	(20.0)
Insurance	33	26	(78.8)	15	11	(73.3)	4	4	(100.0)	4	0	(0.0)	10	7	(70.0)
Real Estate	26	20	(76.9)	7	6	(85.7)	3	3	(100.0)	2	0	(0.0)	4	3	(75.0)
Software & Services	15	11	(73.3)	22	12	(54.5)	1	1	(100.0)						
Technology Hardware & Equipment	14	9	(64.3)	32	20	(62.5)	22	22	(100.0)	1	0	(0.0)			
Semiconductors & Semiconductor Equipment	4	2	(50.0)	16	9	(56.3)	3	3	(100.0)						
Telecommunication Services	21	16	(76.2)	6	6	(100.0)	3	3	(100.0)	5	4	(80.0)	1	1	(100.0)
Utilities	34	32	(94.1)	27	20	(74.1)	2	1	(50.0)	3	2	(66.7)	3	1	(33.3)
	Brazil			China			India			South Africa			Turkey		
	N	Adoption		N	Adoption		N	Adoption		N	Adoption		N	Adoption	
Energy	1	0	(0.0)				3	3	(100.0)	1	1	(100.0)	2	2	(100.0)
Materials	6	3	(50.0)	1	1	(100.0)	11	10	(90.9)	16	13	(81.3)	3	1	(33.3)
Capital Goods	3	1	(33.3)	2	2	(100.0)	2	2	(100.0)	10	4	(40.0)			
Commercial & Professional Services															
Transportation	3	2	(66.7)	1	0	(0.0)				3	3	(100.0)	1	1	(100.0)
Automobiles & Components				1	0	(0.0)	2	2	(100.0)						
Consumer Durables & Apparel	3	1	(33.3)	1	1	(100.0)				1	1	(100.0)	5	4	(80.0)
Consumer Services							1	0	(0.0)	1	0	(0.0)	1	0	(0.0)
Media															
Retailing	1	1	(100.0)							5	2	(40.0)			
Food & Staples Retailing	1	0	(0.0)							4	3	(75.0)			
Food, Beverage & Tobacco	3	2	(66.7)				2	2	(100.0)	4	3	(75.0)	1	1	(100.0)
Household & Personal Products	1	1	(100.0)												
Health Care Equipment & Services	1	0	(0.0)												
Pharmaceuticals, Biotechnology & Life Sciences							1	1	(100.0)	3	2	(66.7)			
Banks	4	3	(75.0)				5	2	(40.0)	2	0	(0.0)	5	2	(40.0)
Diversified Financials	3	1	(33.3)				2	1	(50.0)	3	3	(100.0)	1	0	(0.0)
Insurance	1	0	(0.0)							7	5	(71.4)			
Real Estate	1	0	(0.0)							6	3	(50.0)			
Software & Services										2	2	(100.0)			
Technology Hardware & Equipment				3	2	(66.7)	7	7	(100.0)						
Semiconductors & Semiconductor Equipment															
Telecommunication Services	2	1	(50.0)							3	1	(33.3)	1	0	(0.0)
Utilities	12	7	(58.3)				3	1	(33.3)				1	0	(0.0)

The column “N” shows the number of all firms in the data set for a specific country. The column “Adoption” denotes the number of firms that have mitigation targets, followed the percentage of the firms with mitigation targets in brackets. For sectors with zero firms we leave the entry blank.

ETS. Actually, Japanese firms have a long-established history of taking very proactive stance on environmental issues. For example, Japan has the biggest number of IOS14001-certified plants in the world [44]. The resource-scarcity of the country, the governmental focus on Clean Development Mechanism, and the traditional emphasis on lean operations in corporate culture can be critical drivers behind the high target adoption rate.

It is rather surprising to learn that firms in Australia and Canada lag behind those of the other countries, even the developing ones. Several factors may contribute to the low target adoption rates. First, both countries have been known for their weak and often capricious national climate policies [45,46]. Australia and Canada participated in the first commitment period of Kyoto Protocol in 2008–2012. But Australia did not ratify the treaty until 2008. Canada backed down from the national emission reduction obligations signed in the Kyoto Protocol and

eventually withdrew from the treaty in 2012. Also, both countries belong to the highest per capita GHG emitters as a result of resource-driven economies, and have “vacillated between support for and obstruction of strong international climate agreements” [39]. Lack of consistent commitment to mitigation at the national level will evoke weak responses from the private sector. Sector-wise, in both countries, the Materials sector has notably low adoption rates (43.48% for Canada and 26.67% for Australia), far below that of the other countries, even the developing ones (75.68%). Most of the firms in the Materials sector of the two countries are metals and mining companies, such as Barrick Gold Corporation and Teck Resources in Canada, and Alumina and Sundance Resources in Australia. The sector constitutes a considerable segment in the national economy of the two countries. While mining companies realize the threat of climate change, they are not taking actions due to economic and policy concerns [47].

The results on target metrics also show interesting patterns. In general, developing countries have a relatively larger fraction of firms that adopt intensity targets (42.47%) than the fraction of firms with absolute targets (28.49%). This can be explained by the argument that intensity targets can better accommodate economic growth and hence are more appealing than absolute targets to entities with high economic growth. At the country level, major developing countries prefer intensity targets (emissions per GDP) to avoid penalizing economic growth [48]. Representative developing countries such as China and India have long measured their climate performance in terms of carbon intensity of GDP. In the INDCs submitted for Paris Agreement, both China and India use intensity metrics. Japan dominates the other countries in the simultaneous use of absolute and intensity target (41.72%). The EU tracks Japan in the simultaneous use of absolute and intensity targets (21.74%).

Table 2 also shows there are significant dispersions of target-setting strategies across sectors in the same country and for the same sector across different countries. The divergence of target use across the sectors can be caused by regulatory and operational features of individual sectors. Sectors with lower GHG emissions in operations usually bear less regulatory and market pressure [49]. These sectors include Consumer Durables & Apparel, Diversified Financials, Food & Staples Retailing, and Software & Services. Because regulatory and market pressure can stimulate environmental practices [49,50], it is natural to expect that the sectors with lower GHG emissions are laggards in adopting emission targets.

5.2. Target scope

The scope of a target is defined based on the sources of emissions covered in the target in relation to the firm's boundary. Scope 1 emissions represent direct emissions from the firm's own facilities. For instance, a firm's scope 1 emission includes emissions from the firm's vehicle fleet, boiler and furnace. Scope 2 emissions are indirect emissions associated with the generation of energy acquired and consumed by the firm. For instance, a firm need to procure a certain amount of electricity from the utility company, and the emission of the utility company to generate the electricity is included in the firm's scope 2 emission. All the indirect emissions in a firm's supply chain excluding scope 2 emissions are included in scope 3 emissions. A firm can employ multiple targets that cover emissions from different scopes. In fact, scope 1 and scope 2 targets constitute the basis of target adoption, in that if a firm establishes a target, the target always covers scope 1 or scope 2 emissions or both. Consequently, the use of scope 1 and scope 2 targets across the countries and sectors exhibits similar patterns as target adoption in Section 5.1. Therefore, in our analysis, we focus on targets on scope 3 emissions, the distribution of which is not synchronized with target adoption.

While policymakers and researchers have generally acknowledged the importance of scope 3 emissions, in practice scope 3 emissions are hard to measure, due to lack of understanding, motivation or technical capability [51]. Indeed, emission regulations such as cap-and-trade and carbon tax do not go beyond the firm boundary to tap into emissions in supply chain. The economic benefits for a firm to reduce scope 3 emissions are also limited compared to benefits of mitigating scope 1 and scope 2 emissions. Thus there is insufficient regulatory pressure and economic incentive for firms to limit scope 3 emissions. Because of these reasons, firms usually have to surmount higher barriers to institute scope 3 targets [52]. Table 3 shows the use of scope 3 targets for firms that have emission targets by sectors.

Among the developed countries, the fraction of the EU firms that set up targets on scope 3 emissions (40.1%) is the highest among the countries. The prevalence of scope 3 targets among the EU firms is partially in line with [8], which shows that UK retailers are more prone to addressing supply chain emissions than the US retailers. Our study greatly extends the breadth of firms under study beyond UK and US

retailers to firms in all sectors around the world. Canadian firms have an astonishingly low adoption rate of scope 3 targets (13.3%). Japanese and Australian firms perform relatively well with adoption rates of 35.4% and 35.7%. The fraction of the US firms that set scope 3 target is 22.8%. Among the developing countries, none of the Chinese firms set scope 3 targets. The absence of supply chain emissions in targets of Chinese firms may correspond to a lack of attention to emissions beyond the firm boundary. The other four developing countries have intermediate to high levels of adoption rates for scope 3 targets. Turkey is an outlier with a surprisingly high adoption rate of 45.5%, even higher than that of the EU. Overall, Canadian and Chinese firms are laggards in the use of scope 3 targets, and the EU and Turkish firms are most proactive in this regard.

5.3. Target stringency

Target stringency is represented by the annual magnitude of mitigation. A larger annual emission reduction indicates, *ceteris paribus*, a more difficult mission for the firm to accomplish the target. Table 4 illustrates the target stringency distribution for firms with targets by sectors. Ideally, the mean mitigation for a sector should be calculated using the firms' reference year emissions as the weights. However, many firms do not report the base year emissions, and consequently there is no way to derive the weights. Therefore, we instead calculate the arithmetic average.

Table 4 indicates the US firms set slightly more stringent targets (3.14% mitigation rate) than the EU firms (3.01% mitigation rate). Both EU and US firms tend to be more aggressive in setting emission targets than other countries in the study. For developing countries, the Canadian firms have the lowest mitigation rate of 1.00%. Rather surprisingly, the Japanese firms on average aim to mitigate emissions at a rate of only 1.08%, the second lowest one among the countries and in a sharp contrast with the country's high target adoption rate. Of the 24 sectors, Japan has the lowest mitigation rate among the countries in 10 sectors. Notably, the Food & Staples Retailing and Energy sectors have astonishingly low mitigation rates (0.06% and 0.11% respectively). The low mitigation rate of the Japanese firms implies that despite they are more proactive in establishing the targets, they are less aggressive than firms in other developed countries in setting the amount of emissions to be reduced. Compared to the developed countries, the five developing countries all have lower mitigation rates, ranging from 0.61% for Brazilian firms to 0.73% for Indian firms. Therefore, firms in developing countries set less stringent targets than the firms in developed countries.

5.4. Corporate targets and national targets

In this section, we investigate whether the firm targets are compatible with the countries' overarching national targets. We are particularly interested in the INDCs submitted for the Paris Agreement. As a historic milestone, the Paris Agreement sets out a global and legally binding deal for 195 nations that sign the agreement and paves the way for future mitigation and adaptation. The CDP data provide a snapshot of the firm-level mitigation targets before the Paris. Are these firm-level targets as stringent as the INDCs? To answer the question, we first summarize the INDCs of major countries in the paper in Table 5.⁵

For both corporate targets and INDCs, the reference year serves as a yardstick to measure the magnitude of mitigation. If a firm benchmarks its mitigation target against a reference year different from that of the INDC, as is often the case, we cannot compare its mitigation target and the INDC directly. To make a meaningful comparison, we need to convert corporate targets and INDCs into the same reference year. In

⁵ The INDCs are extracted from <http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx>.

Table 3
Adoption of scope 3 targets by country and industrial sector.

	EU			US			Japan			Canada			Australia		
	N	Scope 3		N	Scope 3		N	Scope 3		N	Scope 3		N	Scope 3	
Energy	14	4	(28.6)	10	1	(10.0)	3	0	(0.0)	13	0	(0.0)	5	1	(20.0)
Materials	50	7	(14.0)	21	1	(4.8)	22	6	(27.3)	10	0	(0.0)	4	1	(25.0)
Capital Goods	70	24	(34.3)	25	6	(24.0)	29	12	(41.4)	1	0	(0.0)	3	0	(0.0)
Commercial & Professional Services	18	8	(44.4)	11	3	(27.3)	3	2	(66.7)	2	0	(0.0)	3	0	(0.0)
Transportation	26	6	(23.1)	12	1	(8.3)	6	0	(0.0)	3	0	(0.0)	2	1	(50.0)
Automobiles & Components	12	6	(50.0)	6	3	(50.0)	9	3	(33.3)						
Consumer Durables & Apparel	13	7	(53.8)	14	2	(14.3)	9	3	(33.3)	1	0	(0.0)			
Consumer Services	14	4	(28.6)	10	2	(20.0)				1	0	(0.0)	2	0	(0.0)
Media	17	10	(58.8)	5	2	(40.0)	2	1	(50.0)	2	1	(50.0)			
Retailing	13	6	(46.2)	15	2	(13.3)	4	1	(25.0)	2	1	(50.0)	1	0	(0.0)
Food & Staples Retailing	12	6	(50.0)	3	3	(100.0)	2	0	(0.0)				2	1	(50.0)
Food, Beverage & Tobacco	18	4	(22.2)	23	5	(21.7)	5	4	(80.0)	1	0	(0.0)	2	1	(50.0)
Household & Personal Products	6	2	(33.3)	8	1	(12.5)	4	2	(50.0)						
Health Care Equipment & Services	7	2	(28.6)	10	2	(20.0)									
Pharmaceuticals, Biotechnology & Life Sciences	11	4	(36.4)	13	2	(15.4)	5	1	(20.0)				1	0	(0.0)
Banks	30	17	(56.7)	7	1	(14.3)	2	2	(100.0)	3	2	(66.7)	4	3	(75.0)
Diversified Financials	12	7	(58.3)	12	4	(33.3)	5	1	(20.0)				1	0	(0.0)
Insurance	26	17	(65.4)	11	3	(27.3)	4	1	(25.0)				7	3	(42.9)
Real Estate	20	5	(25.0)	6	1	(16.7)	3	0	(0.0)				3	2	(66.7)
Software & Services	11	8	(72.7)	12	4	(33.3)	1	0	(0.0)						
Technology Hardware & Equipment	9	6	(66.7)	20	5	(25.0)	22	11	(50.0)						
Semiconductors & Semiconductor Equipment	2	2	(100.0)	9	2	(22.2)	3	1	(33.3)						
Telecommunication Services	16	9	(56.3)	6	1	(16.7)	3	0	(0.0)	4	2	(50.0)	1	1	(100.0)
Utilities	32	13	(40.6)	20	9	(45.0)	1	1	(100.0)	2	0	(0.0)	1	1	(100.0)
Overall	459	184	(40.1)	289	66	(22.8)	147	52	(35.4)	45	6	(13.3)	42	15	(35.7)
	Brazil			China			India			South Africa			Turkey		
	N	Scope 3		N	Scope 3		N	Scope 3		N	Scope 3		N	Scope 3	
Energy							3	0	(0.0)	1	1	(100.0)	2	2	(100.0)
Materials	3	0	(0.0)	1	0	(0.0)	10	3	(30.0)	13	0	(0.0)	1	0	(0.0)
Capital Goods	1	0	(0.0)	2	0	(0.0)	2	0	(0.0)	4	1	(25.0)			
Commercial & Professional Services															
Transportation	2	0	(0.0)							3	0	(0.0)	1	0	(0.0)
Automobiles & Components							2	0	(0.0)						
Consumer Durables & Apparel	1	1	(100.0)	1	0	(0.0)				1	0	(0.0)	4	0	(0.0)
Consumer Services															
Media															
Retailing	1	1	(100.0)							2	1	(50.0)			
Food & Staples Retailing										3	0	(0.0)			
Food, Beverage & Tobacco	2	0	(0.0)				2	0	(0.0)	3	1	(33.3)	1	1	(100.0)
Household & Personal Products	1	1	(100.0)												
Health Care Equipment & Services										2	1	(50.0)			
Pharmaceuticals, Biotechnology & Life Sciences							1	0	(0.0)						
Banks	3	2	(66.7)				2	1	(50.0)	3	3	(100.0)	2	2	(100.0)
Diversified Financials	1	1	(100.0)				1	0	(0.0)	5	2	(40.0)			
Insurance										3	2	(66.7)			
Real Estate										2	1	(50.0)			
Software & Services							7	3	(42.9)						
Technology Hardware & Equipment				2	0	(0.0)									
Semiconductors & Semiconductor Equipment															
Telecommunication Services	1	0	(0.0)							1	0	(0.0)			
Utilities	7	0	(0.0)				1	0	(0.0)						
Overall	23	6	(26.1)	6	0	(0.0)	31	7	(22.6)	46	13	(28.3)	11	5	(45.5)

The column “N” shows the number of firms that have set up targets. The column “Scope 3” denotes the number of firms that have scope 3 emissions covered in target, followed the percentage of the firms with scope 3 targets out of the firms with targets. For sectors with zero firms we leave the percentage entry blank.

this study we use the firm's reference year as the base for comparison, by transforming the INDC's reference year into the base using the country's historical emissions. For instance, in 2013 the retailing company Home Depot indicates that it plans to reduce its total emissions by 18% from its reference year 2004 level by the target year 2015. Meanwhile, in INDC the US government pledges that the country will reduce 26–28% emissions from its 2005 level by 2025. We employ the most aggressive value of 28% in comparison. This 28% mitigation from 2005 US emission level can be transformed to the base year 2004 as $28 \times (\text{US Emission}_{2005})/(\text{US Emission}_{2004}) = 28.03\%$ mitigation from the 2004 US emission level ($\text{US Emission}_{2005} = 7313 \text{ MtCO}_2\text{e}$, $\text{US Emission}_{2004} = 7305 \text{ MtCO}_2\text{e}$). Therefore, the US INDC implies an annual mitigation of $28.03\%/(2025-2004) = 1.33\%$ from the 2004

emission level. Home Depot's target corresponds to an annual mitigation of $18\%/(2015-2004) = 1.64\%$ from the 2004 emission level. So the firm's annual mitigation is 0.31% more stringent than the country's INDC. Using this computation method, we can calculate the annual mitigation rates for corporate targets and INDCs for comparison. Fig. 2 reports the histogram of the difference between the firms' mitigation targets and the countries' INDCs. We include Japan, Canada and Australia in the computation for overall result in panel (a), but do not single out each country due to the small size of data.

Overall, for firms that set up mitigation targets, only a small fraction (5.25%) has targets more lenient than the INDCs. Most of the firms have annual mitigation rates 0–3% higher than the annual mitigation rates implied by INDCs. The EU, the US, and the developing countries display

Table 4
Average annual mitigation rates by industrial sectors.

	EU	US	Japan	Canada	Australia	Brazil	China	India	South Africa	Turkey
Energy	3.94	2.25	0.11	1.28	1.07					
Materials	1.94	1.16	1.06	0.94	0.75	0.50		0.91	0.81	0.33
Capital Goods	2.84	3.02	1.32	0.32		0.33			0.40	
Commercial & Professional Services	3.28	2.71	0.75	1.42	1.64					
Transportation	4.56	1.16	0.72	0.89		0.67				
Automobiles & Components	1.92	2.77	1.19							
Consumer Durables & Apparel	3.30	2.16	1.27	0.80		0.33			1.00	0.80
Consumer Services	1.64	2.62		0.78						
Media	4.69	2.60	1.09	0.41						
Retailing	3.50	5.10	0.26	1.00	0.75	1.00			0.40	
Food & Staples Retailing	1.75	4.47	0.06		0.72				0.75	
Food, Beverage & Tobacco	2.91	2.19	1.47	0.56	2.56	0.67		1.00	0.75	1.00
Household & Personal Products	3.22	1.83	2.36			1.00				
Health Care Equipment & Services	2.75	3.81							0.67	
Pharmaceuticals, Biotechnology & Life Sciences	2.12	2.38	0.61		0.63			1.00		
Banks	3.63	2.57	2.37	1.28	1.95	0.75		0.40	1.00	0.40
Diversified Financials	3.05	2.55	0.56		2.52	0.33		0.50	0.71	
Insurance	3.73	2.02	1.23		2.67				0.50	
Real Estate	3.14	9.34	0.18		2.76				1.01	
Software & Services	2.84	5.43	0.18					0.98		
Technology Hardware & Equipment	3.79	2.86	2.07				0.67			
Semiconductors & Semiconductor Equipment	2.70	2.64	0.62							
Telecommunication Services	3.23	3.04	3.12	2.68	15.00	0.50			0.33	
Utilities	1.68	4.57		0.70	0.32	0.58		0.33		
Overall	3.01	3.14	1.08	1.00	2.56	0.61	0.67	0.73	0.69	0.63

Target stringency is represented by the annual mitigation rate (in percentage) implied by the target. For sectors with zero firms we leave the entry blank.

Table 5
INDCs submitted to Paris Agreement.

Country	Reference Year	Target Year	Reduction	Metric
EU	1990	2030	40%	Total
US	2005	2025	26–28%	Total
Japan	2013	2030	26%	Total
Canada	2005	2030	30%	Total
Australia	2005	2030	26–28%	Total
Brazil	2005	2025	37%	Total
China	2005	2030	60–65%	Carbon intensity of GDP
India	2005	2030	33–35%	Carbon intensity of GDP
South Africa	2005	2025–2030	5%	Total
Turkey	2030 (Business as Usual)	2030	21%	Total

For Paris Agreement, South Africa pledges to reduce its GHG emissions to between 398 and 614 MtCO₂e by 2025–2030. To facilitate comparison, we benchmark the most ambitious goal, 398 MtCO₂e, against the country's 2005 emissions of 420 MtCO₂e to derive the reduction rate. Turkey sets a target of 21% reduction against the business as usual (BAU) scenario at 2030.

similar patterns. These results are encouraging. They demonstrate that even before the Paris Agreement, the targets set by the firms tend to be more stringent than the INDCs. Thus, for firms with mitigation targets, target stringency is not a critical and urgent problem to be fixed, at least, for the current moment. What matters more is whether the firms can accomplish the targets or not. To answer the question, we need to examine the specific mitigations actions carried out by the firms. CDP does ask the firms to report their mitigation actions, including the type of the action and the investment. However, only a small fraction of firms has disclosed detailed information on their mitigation actions. No conclusive results can be reached and we leave the question for future research.

Another intriguing question is how the target stringency has evolved over time. To answer the question, we need to know when the targets were set up. CDP data do not report the setup date directly. Instead, firms are requested to report the percentage of time that has elapsed since the setup date toward the target year. This percentage value

coupled with target year enables us to deduce the setup date of the target. For example, in CDP 2013 survey, McCormick & Company disclosed that the company had a target year of 2015 and the time to the target year had elapsed by 50% in 2012. Using the information, we can deduce that McCormick & Company set up the target in 2009, i.e., $2015 - (2015 - 2012)/(1 - 50\%) = 2009$. Fig. 3 plots the difference between firm targets and INDCs in terms of stringency as a function of the target setup year for the EU, the US, the developing countries and countries worldwide. We do not plot individual graphs for Australia, Canada and Japan, because the sample size for these countries is too small. In all four panels, the target stringency relative to INDCs has substantially increased from 2005 to 2012, eluding to tightened objectives set by firms. But the trend is not always monotonic. The target stringency of the EU firms exhibits very dramatic changes. The ups and downs of target stringency may be linked to political and economic events such as climate change summits and economic crisis. The US and developing countries show a clear and relatively consistent upward trend from 2005 to 2012. It indicates that over the years the firms in the US and developing countries have been setting increasingly stringent targets.

5.5. Corporate targets and renewable energy

Since target-setting is a precondition for mitigation actions, it is important to analyze whether and how target-setting leads to specific mitigation actions. Of particular interest to our study is the relationship between targets and the use of renewable energy by the firms. In practice, firms can acquire renewable energy in various ways, such as installing rooftop photovoltaic systems, replacing conventional fuel with biofuel for corporate fleet, or simply purchasing green electricity in the market. Are firms with mitigation targets more likely to use renewable energy? Do more stringent targets result in more investment in renewable energy? We aim to address these questions in this section.

CDP database provides us with data on firms' investment in renewable energy. In analyzing the investment in renewable energy, we need to consider various factors that can affect firms' investment decisions, such as firm size, R&D activities and leverage. Since we only have data on these factors for US firms (the data are obtained from the

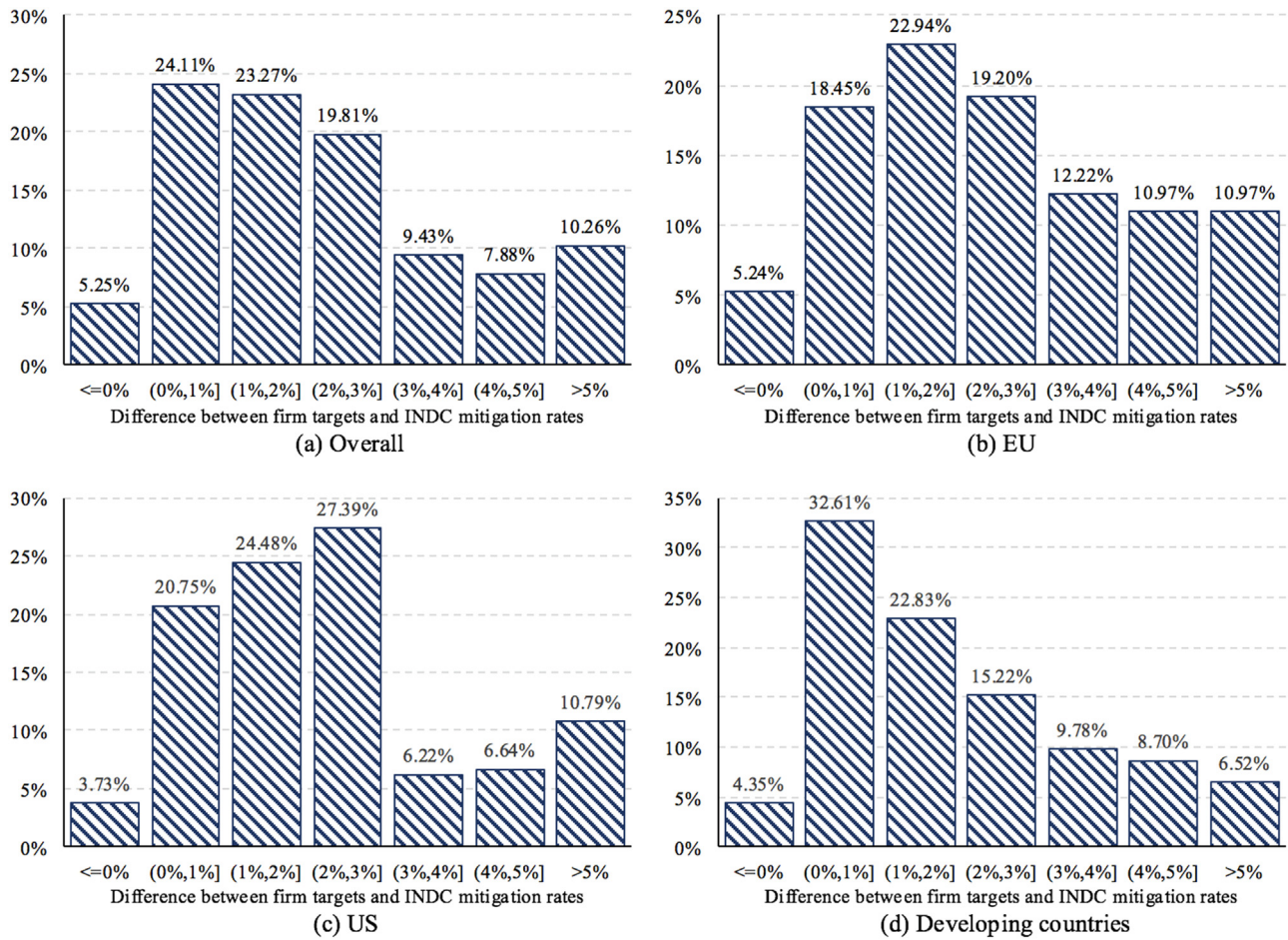


Fig. 2. Histogram of the difference between firm targets and INDCs in terms of annual mitigation rates. (For the US, we use the INDC of 28% in computation. South Africa designates a time range as the deadline in its INDC and we use the most recent year 2025 in computation. The total emissions of China, India and Turkey will increase, as implied by the metrics employed in their INDCs. For these countries, we use 0% as the national goal).

Compustat, a standard database of firms' financial and market information), we examine the relationship between targets and renewable energy investment for the US firms only. Our analysis is based on the following two regression models:

$$Y_i = \phi(\beta_0 + \beta_1 X_i + \beta_K Controls_i + \beta_I Industry + \epsilon_i), \quad (1)$$

and

$$\text{Log}(Z_i) = \beta_0 + \beta_1 X_i + \beta_K Controls_i + \beta_I Industry + v_i. \quad (2)$$

In (1) and (2), Y_i refers to whether firm i invests in renewable energy; Z_i refers to the amount of investment in renewable energy, and is log-transformed due to right-skewed pattern of investment data (as a common technique in logarithm transformation, for firms reporting zero investment, we replace 0 with a small number 1 to compute the logarithm); $\phi(\cdot)$ refers to the logistic function; X_i includes the variables of interest, i.e., target adoption and target stringency; ϵ_i and v_i are the error terms. The term *Controls* includes several control variables. Firm size is expected to have a positive effect on the use of renewable energy, because larger firms have more resources to make the investment than smaller ones. Also, large firms are generally more visible to policymakers and customers, and hence may bear stronger pressures on climate change. We control for firm size with the natural logarithmic of total assets. Prior studies indicate that technological capability of a firm can impact the firm's use of environmental technology. Therefore, we include *R&D intensity*, measured by the ratio between R&D expense and sale, to proxy the technological capability of the firm. A firm's leverage is known to affect its investment decisions. *Leverage* is calculated as long-term debt scaled by total assets. A firm's investment decision may

depend on its current carbon emission. Therefore, we introduce *carbon intensity*, defined as the total direct and indirect emissions scaled by total assets. Further, we capture industry-specific effects by including a dummy variable *Industry* that is codified based on 1-digit Standard Industrial Classification code. Moreover, we need to remove private firms because Compustat only provides data on public firms. Eventually we obtain a sample of 334 firms.

We estimate model (1) with logistic regression and model (2) with ordinary least squares regression. Table 6 reports the regression results. It turns out that the dichotomous variable target adoption is a positive and significant predictor of investing in renewable energy ($\beta = 0.772$; $p < 0.01$) and the amount of investment in renewable energy ($\beta = 0.587$; $p < 0.05$). The results indicate that firms adopting GHG mitigation targets are more likely to invest in renewable energy, and having mitigation targets leads to higher investment in renewable energy. The nonsignificant coefficients for target stringency indicate that there is no evidence that more aggressive targets lead to more investment in renewable energy. This is probably owing to the fact that a range of mitigation technologies (energy efficiency, green design, etc.) are available, and renewable energy may not be the most economically desirable option for achieving deeper emission cuts [53].

6. Discussions

Firms in countries other than the EU should increasingly incorporate scope 3 emissions into target-setting. First and foremost, even though a firm's scope 3 emissions are generated by facilities outside the

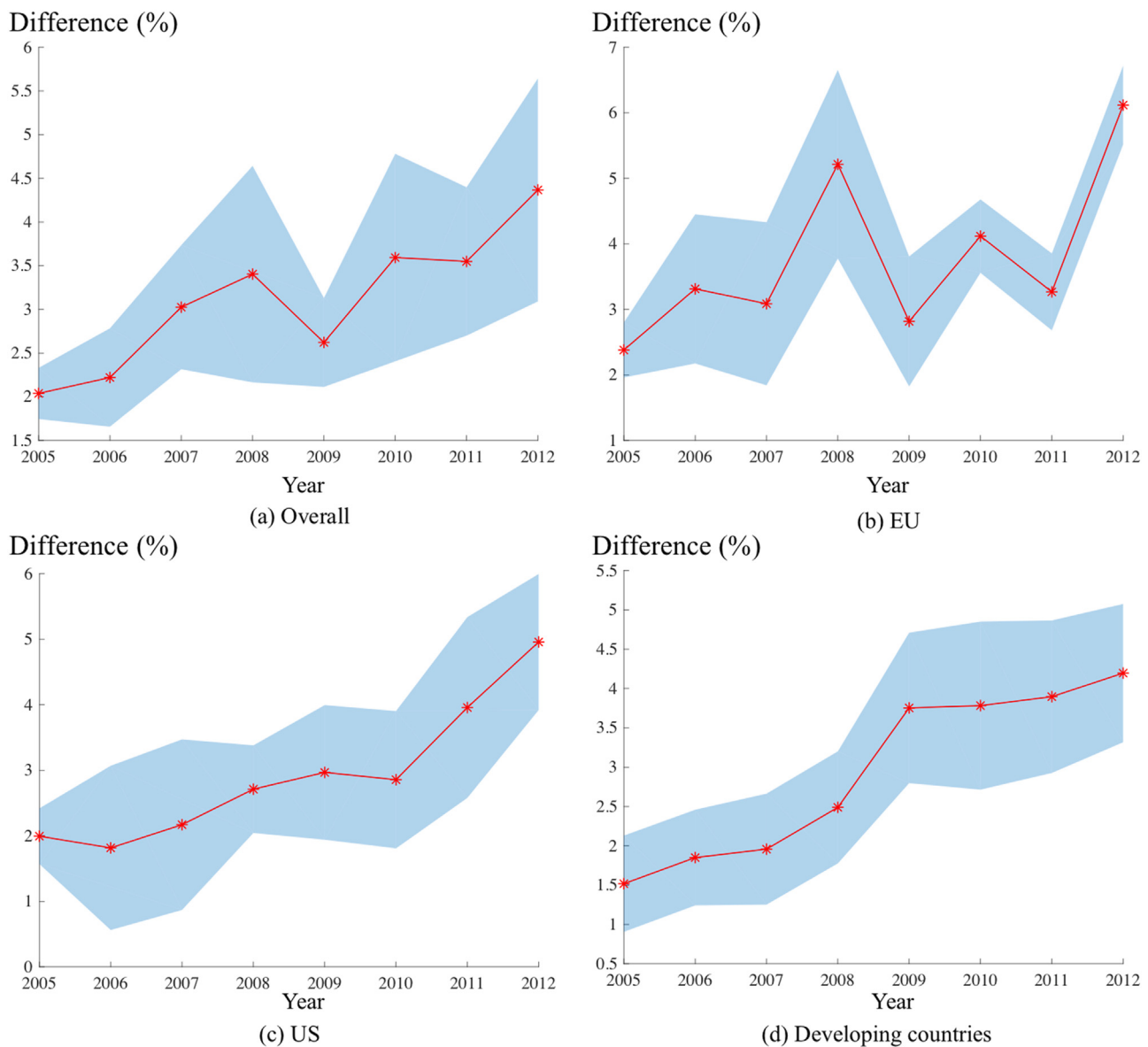


Fig. 3. Change of the difference between firm's targets and country's INDCs over time in terms of annual mitigation rates. (The line shows the annual average difference and the shaded area shows the 95% uncertainty range. We include Japan, Canada and Australia in the computation for overall result in panel (a).).

firm's boundary, they arise as a result of the firm's business activities. Therefore, it is reasonable that the firm should be accountable, at least partially, for scope 3 emissions it causes [54]. Furthermore, the scope 3 emissions represent a substantial segment (more than 75%) of an industrial sector's carbon footprint and the sheer volume makes them impossible to ignore [51]. Despite the recognition that scope 3 emissions have to be incorporated into mitigation agenda [55], difficulties with measurement of scope 3 emissions have made it hard to do so [51]. New standards have been developed recently for estimating the scope 3 emissions (e.g., Corporate Value Chain Standards developed in the GHG Protocol).⁶ Firm management may consult those protocols.

Moreover, policymakers in all countries should make efforts to ensure the transparency of the targets set up by the corporates. Transparency allows other parties such as the government and media to monitor how the firms are progressing toward the targets. Transparency can also boost competitive pressure among the firms to set more

ambitious targets. To ensure transparency, policymakers can enforce the disclosure of targets on climate change in firms' annual filings through securities law. In the US, the Securities and Exchange Commission (SEC) issued the Commission Guidance Regarding Disclosure Related to Climate Change (SEC FR-82) in 2010, to mandate the disclosure of certain climate change-related issues in 10-K annual reports. But disclosure of firm target is not part of the guidance. In fact, no country in our sample requires mandatory target disclosure for firms. On the other hand, mandatory disclosure can be hugely controversial, as in the case of SEC FR-82. Voluntary programs can be more desirable sometimes. For instance, to incentivize target disclosure, policymakers may recognize corporates that disclose mitigation targets, through programs like EPA's Climate Leadership Awards in the US.

Canadian policymakers should first focus on promulgating the use of targets in the private sector to catch up with other countries in target adoption. As we have suggested, the low adoption rate reflects the lack of commitment to carbon mitigation in Canada's national policies. Therefore, a natural remedy is a revamp of climate change policies at the national level. However, enacting more supportive national policies for climate mitigation can be a quite difficult and lengthy process.

⁶ <http://www.ghgprotocol.org/standards/scope-3-standard>, accessed on September 1st, 2017.

Table 6
Regression results.

Model:	(1)	(2)
Dependent variable:	Whether renewable energy is used	Investment amount in renewable energy
<i>Constant</i>	0.295 ^{***} [0.072]	− 2.065 [1.316]
<i>Target adoption</i>	0.772 ^{***} [0.183]	0.587 ^{**} [0.203]
<i>Target stringency</i>	0.113 [0.157]	0.100 [0.290]
<i>Firm size</i>	0.121 ^{**} [0.056]	0.235 ^{**} [0.103]
<i>Leverage</i>	− 0.924 ^{**} [0.491]	0.788 [1.077]
<i>R&D intensity</i>	0.656 [1.261]	3.271 [2.249]
<i>Carbon intensity</i>	− 0.037 [0.065]	0.192 [0.122]
<i>Industry dummy</i>	Yes	Yes
<i>Firms</i>	334	334
<i>Adjusted R²</i>	0.218	0.084

Standard errors are reported in brackets.

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

Consequently, regulations at the province level may be a more convenient approach in the near term. There are indeed encouraging progresses in this respect. For example, Quebec in Canada has implemented its provincial carbon cap-and-trade system in 2013 for companies with an annual emission quantity of more than 25,000 metric tons of CO₂e. More recently, Ontario in Canada passed landmark cap-and-trade legislation.⁷ Those provincial legislations, if properly designed, would boost the use of mitigation targets. The analysis can be extended to Australian firms since they face similar problems as the Canadian firms.

The most remarkable difference between the targets of the developing countries and those of the developed ones lies in mitigation rate. The result implies that for policymakers in developing countries, promoting the adoption of mitigation targets among the firms may not be the most pressing mission, and it is more imperative to improve stringency of targets. A target is less effective if it does not come with an appropriate degree of stringency.

As in [21], we observe a great divergence among the sectors in terms of target adoption in Table 3. Simple computation shows that the standard deviation of sectoral adoption rate is higher for the developing countries (23.1%) than the developed countries (9.5%). Therefore, developing countries' greater sector divergence implies that their policymakers may take sector-oriented actions. Among the industrial sectors, we can identify leaders and laggards based on target adoption and present the result in Table 7. The Household & Personal Products sector has a perfect adoption rate. Software & Services is a leader for developing countries but lag behind for developed countries. The opposite happens to Telecommunications Services. The Energy sector is a primary GHG emitter. It turns out that the Energy sector of the developing countries is one of the leaders in target adoption, whereas its counterpart in the developed countries does not fare equally well. The performance of an industrial sector can be closely related to the regulations and market conditions the sector is subject to. For instance, the Diversified Financials sector and the Consumer Services sector generally are not the targets for climate regulation. Therefore, the firms are less likely to set up mitigation targets, as shown in Table 7.

The target-setting behavior may be influenced by various factors,

Table 7
Leaders and laggards in the sectors in terms of target adoption.

Developed countries	Developing countries
<i>Leaders:</i> Household & Personal Products (100%) Food, Beverage & Tobacco (90.7%) Telecommunication Services (83.3%)	<i>Leaders:</i> Household & Personal Products (100%) Software & Services (100%) Energy (85.7%)
<i>Laggards:</i> Software & Services (63.2%) Semiconductors & Semiconductor Equipment (60.9%) Diversified Financials (55.6%)	<i>Laggards:</i> Telecommunication Services (33.3%) Pharmaceuticals, Biotechnology & Life Sciences (33.3%) Consumer Services (0%)

The leaders and laggards are defined as the top three and bottom three sectors in terms of target adoption. The adoption rate is shown in parentheses.

including firm size, capital constraint and regulatory pressure. An early study has investigated the determinant factors behind the targets for the US firms. It is found that firm size, firm growth and government pressure can positively affect the likelihood of adopting mitigation targets [56]. Furthermore, whether or not setting more stringent targets is to appeal to consumers as a public relationship vehicle is an intriguing problem. The problem has already been studied [9]. According to the existing results, firms setting more stringent targets are more likely to achieve the targets. Therefore, setting more stringent targets is not merely a token of climate friendliness.

The significant positive impact of target adoption on the use of renewable energy implies that promoting mitigation targets in the corporate world is very likely to be an effective way to increase penetration of renewable energy. This result is of particular relevance in countries where the development of renewable energy faces strong political oppositions. If policies directly regulating the use of renewable energy are not feasible, encouraging mitigation targets set by the firms may serve as an indirect approach.

7. Conclusions

As a precondition for GHG mitigation actions, target-setting by firms is emerging as a necessary and critical component of the global campaign to address climate change. However, the issue has received little attention in literature. To close the gap in literature, we study the employment of GHG emission targets by major corporations around the world. The analysis focuses on four aspects of the targets, i.e., adoption, metric, scope, and stringency. We find Japanese firms are significantly more proactive than firms in any other countries to institute carbon mitigation targets. Australian and Canadian firms significantly lag behind in target adoption. The EU, the US and the developing countries have intermediate levels of target adoption. The EU firms are the most proactive in including scope 3 emissions in targets. Japanese and Canadian firms set less stringent targets than other countries. The firm targets are generally more stringent than the INDCs submitted by the countries to the Paris Agreement. The target stringency has been significantly raised between 2005 and 2012, even though the trend is not always monotonic. Setting mitigation targets can stimulate the use of renewable energy. However, there is no evidence that target stringency affects the investment amount in renewable energy. The results shed lights on the most crucial issues on target-setting that firms in different countries should tackle.

This study is subject to the following limitations. First, the results are based on self-reported survey responses from the firms. As in any survey-based study, accuracy of the information is likely a concern. Additional steps (e.g., request of third party verification) have been taken by CDP to ensure integrity of the survey responses, but the concern cannot be completely eliminated. Second, while the study has enclosed as many firms as possible, the power of the analysis can be compromised by data limitations for developing countries especially

⁷ <https://news.ontario.ca/ene/en/2016/05/ontario-posts-final-cap-and-trade-regulation.html>, accessed on September 1st, 2017.

China and India, where only a small subset of firms discloses mitigation targets. Therefore, the findings based on the subset do not necessarily paint a target-setting landscape for the entire corporate world. Third, while we have offered explanations for the observed difference of target-setting pattern across countries and sectors, it requires more rigorous analysis and econometric methods to pin down the root causes behind the differences. Finally, ex-post review is crucial for assessing the validity of the target, i.e., whether or not the target has been achieved. However, the CDP survey asks the firms to report on-going targets rather than accomplished targets. Therefore, we do not have the data to carry out ex-post review.

There are three avenues for future research. First, a related and important problem is how the targets translate into mitigation actions. Setting mitigation target is an initial step in response to climate change. Firms need to take follow-up actions to achieve the targets. Whether the mitigation actions match the targets is a critical problem that should be scrutinized. For this problems, data on targets and mitigation actions over a longer time horizon are needed. Second, target-setting as a voluntary mitigation action is affected by the environment in which the firm operates. How the exogenous events such as the approval or repeal of major climate treaty affect firm-level targets is a problem of interest to both policymakers and researchers. Examining this problem requires target-setting data over a longer horizon. Third, how the target features interact with each other is also a critical research problem.

Acknowledgement

The work described in this paper has been supported by the Program for Young Innovative Research Team in China University of Political Science and Law (No. 18CXTD02) and Major Project of National Social Science Foundation of China (No. 15ZDB162).

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